

AN ABSTRACT OF THE THESIS OF

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STUDY UNITS ON DIVERGENT-PRODUCTIVE THINKING AND
NONVERBAL COGNITIVE ABILITIES

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Acquisition of nonverbal cognitive abilities and divergent-productive thinking skills by using Elementary Science Study materials constitutes the basic idea of this experiment. The data collected was used to determine statistically if the materials had a significant role in inducing such skills.

The Ss were sixth-grade students obtained from the Goodview Elementary School in Winona, Minnesota. The Ss selected for the study were randomly assigned to control and experimental groups. Ss completing the experimental activity sessions, were taught for forty-five minutes, three days per week, for eight weeks.

A series of experimental activities using Tangrams and Geo Blocks comprised the treatment to which the experimental Ss were subjected. Divergent production of units, classes, relations, systems, transformations, and implications were an integral part of the activities. Nonverbal

ability activities included puzzle and problem solving by use of two and three dimension pieces of puzzles and blocks.

The posttest consisted of Verbal Form A and Figural Form A of the Torrance Test of Creative Thinking and the Thorndike-Hagen Nonverbal Cognitive Abilities test. These were administered to the experimental Ss and control on three consecutive days following treatment.

Student's t-test were performed on the T-scores and Universal Scale Scores to determine whether or not a significant difference occurred between the means of the two groups.

Nonverbal cognitive abilities were found to be significant at the .02 level. Verbal fluency was found to be statistically significant beyond the .01 level. Verbal flexibility was found to be statistically significant at the .02 level. Verbal originality was found to be statistically significant at the .20 level. Figural flexibility, figural originality, and the composite scores of all divergent thinking tests was found to be statistically significant at the .001 level.

A major recommendation from this study is: elementary school curricula utilize materials that lead to development of particular thinking-skill processes in varied content-oriented ways.

The Effects of Two Selected Elementary Science
Study Units on Divergent-Productive
Thinking and Nonverbal Cognitive Abilities

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THE EFFECTS OF TWO SELECTED ELEMENTARY SCIENCE
STUDY UNITS ON DIVERGENT-PRODUCTION
THINKING AND NONVERBAL COGNITIVE ABILITIES

I. INTRODUCTION

Development of Elementary Science Materials

During the past two decades much investigation and substantial changes in the school curricula have occurred. This has been a direct result of the recent wave of curriculum development projects supported primarily by the National Science Foundation. Many of the educators, psychologists, philosophers, scientists, and businessmen who were responsible for the formulation of the new science curriculums at the elementary level seem to favor a "hands-on" inquiry or problem-solving approach. Many of the innovators in the new science curriculum projects realized the need for a child to be able to think and create in the realm of science; to learn by doing.

The development of modern elementary science programs such as Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), Science - A Process Approach (SAPA), and Experiences in Science (EIS) have used an approach to education which enables children to learn for themselves. This is accomplished by students being involved directly, being able to change, manipulate the subject they are studying, from playing with blocks to

inquiring with microscopes. The child is actively involved in first hand experiences in the processes of science. He learns skills in observing, classifying, measuring, communicating, organizing in time and space, recording data, organizing data, evaluating, hypothesizing, inferring, and experimenting. The newer approaches involve more than just the mere memorization of facts or products. It involves the science processes. It can be contrasted with an approach that treats education primarily as a kind of substance, as so much intellectual content, which is first in the teacher's head and then transmitted to the student's head.

The developers of Elementary Science Study were concerned that many people were unfamiliar with scientific thinking and were reacting to prevailing styles of teaching. According to Philip Morrison, Chairman of the ESS steering committee (1970, p. 1),

There is no use in designing a curriculum now which encompasses everything that is important, because you can be quite sure that 30 years from now many of these things are not going to be so important any more.

In ESS the traditional content and methodology of science teaching is rejected because the developers thought the book, the lecture, and the programmed text were second hand. They serve as skimpy substitutes for first hand communication and experimentation. ESS attempts to find ways

of learning that are concretely involving and aesthetically rewarding. An attempt is made to move from play toward apprenticeship in work.

Walcott, on the staff of ESS, reaffirms a materials centered, child-involved curriculum when he says (1965, p. 1),

We can all agree that facts by themselves are not enough nor, by the same token, are processes, concepts, or any other single purpose approach. For science instruction in particular, all of these methods must be blended into a course of study that is recognizable science. This implies a program that provides real science through materials children can work with, problems they can investigate, and questions they can ask and find answers to for themselves. It is not enough to make marks on the blackboard or to talk a bit ... the essential act of the scientist is abstraction ... that act is his boldest and most difficult one. In it lies his errors as well as his victories, but it is exactly that action which the book, the lecture, the programmed test, never allows the student to share. Only the material can instruct in this process, and only the errors so made can lead to a real and productive understanding.

The ESS materials were developed with a search for answers to the questions that follow: (1) What do six to thirteen year-old children find interesting to explore? (2) What kinds of materials and problems are able to inspire children to look at some part of the world with greater attention and care? and (3) What sorts of questions, answers, organizational schemes, equipment, and the like turn out to be most effective in a variety of classrooms? It is an approach that treats education primarily as a kind

of substance, contrasted as, so much intellectual content. Involving, esthetic, and play are key words in ESS materials.

Each set of materials or units has been trial tested and revised by many teachers and children in many socio-economic levels of society.

Tangrams, an ancient Chinese invention and perhaps the oldest and most enduring of geometric puzzles, consists of a square divided into seven geometric shapes. A great number of geometric and pictorial arrangements can be made with these pieces. The subject matter of this unit is to develop skill in dealing with basic geometric relationships before confronting more complex problems. Many tangram problems are manageable for preschool children and the advanced problems are challenging to most adults. Skill develops through experience. Students explore problems and become skillful in transferring spatial relationships to more complex problems. Extensive attention will be given to tangrams in the study which is to follow.

Geo Blocks are pieces of unfinished hardwood cut into a wide variety of shapes and sizes. These blocks come in shapes and sizes not usually found together in other sets of blocks, and lend themselves to a wide variety of structures and designs -- some simple, some complex. The use of Geo Blocks began in 1962 by Carritt and Churchill (Teachers Guide, Geo Blocks, p. IV). The particular shapes and sizes

are selected for both volumetric relationships and for usefulness in making intricate constructions. There is a large quantity of small blocks and a comparatively small quantity of the larger blocks. In making a large shape out of smaller ones, a child develops a feeling for equivalent volumes in a context that is determined by his own needs and interests. Children enjoy building with blocks. They seem to find it impossible to sit in front of a pile of blocks without putting them into some kind of order such as a building or town. This natural tendency to build provides an outlet for creative energies in much the same way that art work and creative writing do. Children gain some feeling for surface area and volume relationships. A group of blocks can be arranged and rearranged in a variety of shapes, but they remain the same blocks with the same total volume. They seem to grasp this intuitively in their building, though they are not able to say what they know. They do not always seem to recognize, when they first begin building, that a block keeps the same volume in any relationship with other blocks. As the child works with Geo Blocks, his increasing familiarity with volume relationships is fairly easy to notice. It is more difficult to see, but probably of more fundamental importance to the child's development of concepts, the experience he accumulates with different ways in which objects are related to one another. The blocks he arranges in one construction

can be rearranged into a different construction; the buildings he creates look quite different if viewed from another angle, two things can be made which are similar in every way except that one is larger or smaller than the other. A three-dimensional construction can be represented by a two-dimensional projection as in maps. Geo Blocks help lay a foundation which assists to think in terms of three-dimensions of space, and to handle scaling and mapping with understanding. Divergent-Productive Thinking whereby one searches for different directions in arriving at an answer will be given more attention later in the study.

Psychological Bases of Elementary Science Materials

Two contemporary psychological theories are paradigms of educational thought because they relate directly to a materials-centered, child-involved approach to education and also to this study. These theories are those of:

(1) J. P. Guilford, Professor of Psychology at the University of Southern California, and (2) Jean Piaget, Swiss Director of the Jean Jacques Rosseau Institute in Geneva, Switzerland.

Anderson et al. (1970, p. 118), Karplus (1967, p. 20-21), and Thier (1970, p. 71), support teachers and other educators utilizing the results of Piaget's studies in helping to formulate curricula and elementary science materials. Hubbard (1967, p. 40), supports Guilford's model of the

intellect as a means of explaining the basic structure of thinking.

One of the psychological factors of intellectual development about which Piaget writes is that of mental models. Piaget in his book, The Early Growth of Logic in the Child, (1964, p. 280), says:

The ability to establish a mental model is based upon flexibility and persistence; fluidity of thinking ... while rigidity hinders the correct solution.

Development of intellectual capacity goes through a number of stages whose order is constant, but whose time of appearance may vary both with the individual and with the society associated. Each new level of development is a new coherence, in which new structuring of elements occurs until they are related to previous experience.

Four factors contribute to this development. They are nervous maturation, encounters with experience, social transmission, and equilibration or auto-regulation. The first three have a role in intellectual development but each is insufficient in itself. His findings show that an individual's intellectual development is a process of equilibration, where the individual is the active motor and coordinator of his own development.

The first three factors are passive to the individual. Something is done to the learner; his physiological system matures, or he is presented with physical or linguistic

material to absorb. Intellectual development is not passive. This results from activity in which one is involved. An individual learns to see the world as coherent, as structured, to the extent that he acts upon the world, transforms it, and succeeds in coordinating these actions and transformations.

Development proceeds as partial understandings are revised, broadened, and related to one another. Piaget's model is one of auto-regulation to attain broader and more stable equilibrium in the individual's dealing with the world.

The characteristics of "mental models" are consistent with Guilford's (1959) parametric model of the structure of intellect in which flexibility and non-rigidity constitute the category of divergent-productive thinking, a type of thinking that goes searching or takes different directions, the end result being a variety of possible solutions to the problems at hand.

Hull's analysis of the approaches to learning used by children shows that those who are most able to exhibit a certain flexibility of mind with which they deal with more than one aspect of a problem without becoming confused. "A young child's thought," according to Hull (1967, p. 141), "has been called ego-centric because he cannot deal with more than one point of view at a time." Piaget has demonstrated that this skill in dealing with more than one point of view at a time is basic to more advanced reasoning.

Part of being able to think in a divergent-productive manner (from Guilford's model) stems from the ability to form mental models and deal with more than one point of view at a time. Kuslan and Stone (1968, p. 55), tell of the importance of this when they say,

The formation of mental models is important in transfer of learning because it makes possible the application of a consistent explanatory scheme to apparently unrelated phenomena. Until appropriate mental models are formed, children cannot understand the logical necessity of the phenomena they encounter.

Divergent-productive thinking is the ability to produce a variety of solutions when confronted with a problem. It stems from forming a mental model of the objects with which one is confronted and the resulting variety of approaches developed for an answer to the problem posed by the objects.

According to Kuslan and Stone (1968, p. 5),

The formulation of mental models surely has implications for problem solving in science by reasonable and analytical modes of thought. Without a cognitive structure to which to relate the various aspects of the problem, the problem is inevitably left to the vagaries of trial and error.

Developing in children the ability to produce a variety of responses when confronted with problems is a perplexity facing science educators.

This view is supported by Hull's (ESS Reader, p. 27) statement of Learning Strategy and the Skills of Thought by writing,

A child whose learning is narrow and specific because of pressure for quick results will have difficulty when the memory load becomes too great, as it does rather soon in mathematics. It is much better strategy in the long run to have control over a few well-digested general ideas and a good sense of discrimination than it is to be burdened with a mass of poorly assimilated facts and a host of doubts as to their relevance or application.

Dienes (1970, p. 17), reaffirms this by stating,

Young children learn best from their own experiences. The logical relationships that we might wish children to learn, should therefore be embodied in observable relationships between distinguishable attributes such as colour, shape, etc.

As early as 1937, Vygotsky (1962, p. 56), suggested the use of blocks as a means of testing for logical thinking of which divergent-productive thinking is a part. Vygotsky's idea for using blocks lay dormant until Hull developed a block-sorting test using materials similar to Attribute Games and Problems and Carritt and Churchill developed Geo Blocks.

Guilford's Structure of Intellect

Guilford has worked with organizing and developing a theory of intelligence. The result of this work is the development of a unified theory of intellectual abilities

in the form of the structure-of-intellect theory and model. This model is based upon a structure utilizing three parameters: content, operation, and product as shown below in Figure 1.1:

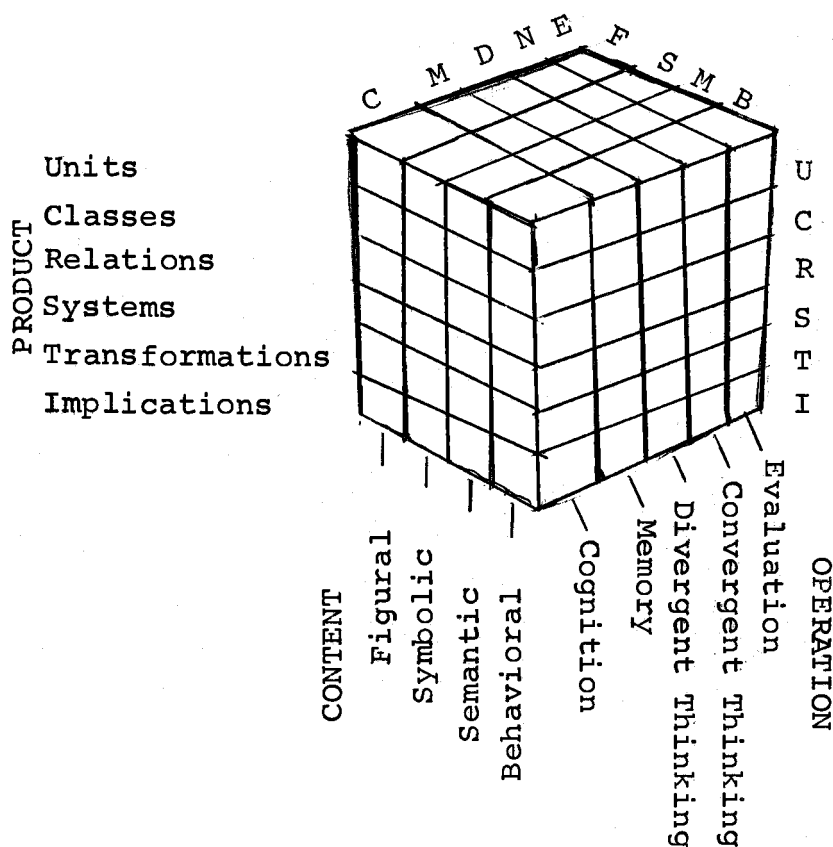


Figure 1.1. Guilford's morphological model of the structure of intellect (after Guilford, 1959).

This model is a basis for classification of abilities according to the materials of thought under content. These abilities pertain to the use of "figural" material. The objects to be dealt with, and their properties, are perceived.

A second class of abilities pertains to the knowing and use of what are called "symbolic" materials. Symbolic

information is in the form of signs, materials, the elements having no significance in and of themselves, such as letters, numbers, musical notation, and other "code" elements.

Semantic information is in the form of meanings to which words commonly become attached and is brought forth in verbal thinking and verbal communication.

Behaviorial content was added to take care of the kind of information involved in cognition and in other operations pertaining to the behavior of other people.

The second basis pertains to the kind of functions or operations or processes involved. This basis gives five classes of abilities. The first kind of operation is cognition. These are abilities to discover or to know and to re-discover or to recognize figural objects and their properties, symbolic objects, and meanings of all kinds. A second kind of operation is that of retention or memory. A third class of operations involves convergent-thinking. This is in contrast to divergent-thinking. In convergent-thinking, the examinee must arrive at one right answer. In divergent-thinking, the thinker must do much searching around, and often a number of answers will do or are wanted.

The last category is that of evaluative abilities. These abilities involve decisions as to goodness, suitability, adequacy, or success of our information, memories, or products of thought. Critical thinking and decision making emphasize this category.

The third major principle of intellectual abilities is that of products. The concept of "product" pertains to the way or form in which any information occurs. Information can be conceived in the form of units - things, segregated wholes, figures on grounds, or "chunks." Units are things to which nouns are applied. A class is a set of objects with one or more common properties. A relation is some kind of connection between two things such as a bridge or connecting link with its own character. Systems are complexes, patterns, or organizations of interdependent or interacting parts, such as a verbally stated arithmetic problem, an outline, a mathematical equation, or a plan or program. Transformations are changes, revisions, redefinitions, or modifications, by which any product of information in one state goes over into another state. An implication is something expected, anticipated, or predicted from given information.

This model allows the placement of any intellectual factor within it by determining the factor's three unique properties. The factor might be cognition of symbolic classes, or convergent-thinking of semantic systems, etc.

The advantage of Guilford's model of the intellect is that it organizes the intellectual factors into a unitary system that is empirically based. It also allows for factor analysis to be made of a matrix of intercorrelations of the factors accepted.

Guilford's model can and has been translated into science-teaching terms. Implications for science learning have been worked out by Hubbard (1967, p. 42-3). The following table serves as a guide to interpreting Figure 1.1 for translating elements of the Guilford model into elementary science teaching terms.

Operations Level - Functioning - Science Learning	
1. Cognition	Understanding terminology of science.
Preceiving and understanding information	Familiarization with historical discoveries.
	Learning theories underlying modern science.
	Acquiring science laboratory skills.
2. Memory	Remembering how to use tools in laboratory science.
Retaining what is learned	Recognizing science concepts, principles, etc.
3. Divergent Thinking	Inventing solutions to new science problems.
Searching for new answers	Reorganizing known information into new concepts.
4. Convergent Thinking	Discovering more precise methods for using materials.
Searching for the right answer.	Refining an ability to explain a concept.
	Producing science materials relative to a standard.

Operations Level - Functioning - Science Learning (continued)

- | | |
|---|--|
| 5. Evaluation | Making for discrimination. |
| Making decisions on goodness or correctness | Employing knowledge and logical argument to appraise science work. |
| | Making judgements. |

 Contents Levels - Kinds of Information

- | | |
|---|---|
| 1. Figural Information representing nothing but itself. | Size, shape, color and space as entities which together compose real objects. |
| 2. Symbolic Coded material | Abbreviations for chemicals, arithmetical computation, etc. |
| 3. Semantic Meaning attached to things | Verbal explanations of science as in history and theory. |
| | Visual organization of figural and symbolic materials. |

 Products Level - Outcomes of Thinking

- | | |
|---|---|
| 1. Units
Single items of thought | Being able to remember an ameoba. |
| | Understanding the concept of a cell. |
| | Discovering how to make a new smell with two chemicals. |
| 2. Classes
Series of Units | Knowing the names of protozoans. |
| | Being able to make subsets of different triangle-shaped blocks. |
| 3. Relations
Relationships between units | Seeing and drawing comparisons between man and apes. |
| | Being able to discriminate between differences of protozoans. |

Products Level - Outcomes of Thinking (continued)

4. Systems Patterns of Units	Understanding the taxonomy of protozoans.
	Understanding a matrix of blocks.
5. Transformations	Reorganizing shapes to make a new system.
	Describing similar historical sequences in biology.
	Learning to see familiar things in an unusual way.
6. Implications Predictions based on available information	Anticipating the outcome of an experiment.
	Foreseeing a trend in one area of science.

Problem Solving and Creative Production

Two complex recognized intellectual activities are problem solving and creative production which are very nearly the same and can be considered basically the same phenomenon. Guilford states (1967, p. 312),

There is something creative about all genuine problem solving, and creative production is typically carried out as a means to the end of solving some problem. Both activities entail transfer recall; if only replicative recall were involved, there would be no problem solving and nothing creative about the behavioral event.

According to Guilford (1967, p. 312) and Merrifield, et al. (1962), "... multivariate experiments involving recognized problem solving tasks fail to find a unitary

dimension that can be called problem-solving ability."

Some of the factors that have been identified with problem-solving and creative production abilities are verabl comprehension, conceptual foresight, originality, and semantic elaboration.

The following matrix of divergent-production factors are represented in the structure of intellect model. These are taken from Guilford (1967, p. 139). The four vertical columns represent the four types of content and six rows for the six types of products. Reference to Figure 1.1 shows this type of matrix. Each of the twenty-four cells represents the single factor, divergent-production. Each cell has a trigram symbol that stands for its unique combination of operation, content, and product, symbolized in order. DFU stands for divergent figural units, and DBI stands for divergent behavioral implications.

A review of literature shows that most workers in the field are concerned with testing the general category of intelligence. The various factors of the matrix were not delineated prior to Guilford's structure of the intellect theory.

This study proposes to use the matrix in Figure 1.2 to delineate the categories involved in teaching divergent-productive thinking using Geo Blocks and Tangrams Units of the Elementary Science Study Program. It will be by comparing empirical results with the matrix cells that acceptance or rejection of a basic hypothesis will be done.

Content				
Figural (F)	Symbolic (S)	Semantic (M)	Behavioral (B)	Product
DFU	DSU	DMU	DBU	Units (U)
DFC	DSC	DMC	DBC	Classes (C)
DFR	DSR	DMR	DBR	Relations (R)
DFS	DSS	DMS	DBS	Systems (S)
DFT	DST	DMT	DBT	Transformations (T)
DFI	DSI	DMI	DBI	Implications (I)

Figure 1.2. Matrix of divergent-production factors (D) represented in the structure of intellect.

Importance of Divergent - Productive Thinking

Productive thinking takes place when new ideas emerge from information that has been gathered. This generation of new information can be classified into two categories: convergent-productive and divergent-productive thinking. Both are necessary for intellectual functioning and essential in dealing with science problems. Convergent thinking is the searching for single answers or "correct" answers. This is exemplified in solving arithmetic problems. Divergent thinking causes one to search or take different directions in arriving at what may be several answers to a

problem. Divergent productive thinking has no one predictable outcome.

Guilford (1967, p. 162), hypothesizes that certain groups of productive people, such as writers, inventors, scientists, mathematicians, artists of various kinds, and manipulators of people, utilize divergent-productive factors in their daily life to realize their goals and achievements. Jones (1960), and Kincaid (1961) found significant correlations in small samples of art students (grades 1-4) and of 46 adults. Fisichelli and Welch (1947) found art majors to be significantly higher in DFS than were unselected students. Torrance (1962) who has done much in development of divergent-productive tests, showed that when a high divergent productive child is placed to work on a problem in a group of five, the other four being lower, the high divergent-productive child initiates ideas far out of proportion.

Maltzman (1960) and Mednick (1962) both bring forth the idea that "original thinkers" can be developed or the ability in a person increased.

If, as the previously mentioned studies suggest, a child's habits and thinking styles along with his attitudes toward learning are thought to be influenced by the conditions of his environment in which learning takes place, then Geo Blocks and Tangrams, may allow for or foster an

atmosphere in which divergent-productive thinking can occur and develop.

Nonverbal Cognitive Abilities

Nonverbal Cognitive Abilities emphasize discovery of and flexibility in manipulating relationships expressed in figural symbols or patterns. This is what has been called "fluid intelligence," which is, abilities not bound by school instruction. Items involve neither words nor numbers, and the geometric or figural elements used bear little direct relationship to formal school instruction.

Nonverbal Cognitive Abilities are closely related to the concept of behavioral unit (DBU) matrix of the Guilford Structure of Intellect model (Guilford 1967, p. 70). Behavioral content is defined as information, essentially nonverbal, involved in interactions.

As early as 1920, E. S. Thorndike had proposed that there is a social intelligence apart from ordinary intelligence, and he defined it as "... the ability to understand and manage people - to act wisely in human relations" (1920, p. 228).

Robert L. Thorndike proposed a factor analysis of social intelligence in 1936. He proposed and constructed tests in pictorial form. He later revised his original forms and now uses figure analogies, figure classification and figure synthesis. This writer proposes to use the

Cognitive Abilities Text Nonverbal Battery - Form 1, by R. L. Thorndike and E. Hagen to see if the use of Tangrams and Geo Blocks will develop Nonverbal Cognitive Abilities.

The development of Geo Blocks and Tangrams makes available materials which this writer feels will develop divergent-productive thinking skills and abilities to work with figures in a pictorial or diagrammatic manner. It is in this light that the following problem is posed.

The Problem

The basic problem of this study is the statistical comparison of treatment applied to an experimental group to determine the effects of Tangrams and Geo Blocks on the acquisition of divergent-productive thinking and nonverbal cognitive abilities with a second group not previously exposed to the treatment materials.

This problem develops from the divergent-productive factor content behavioral unit factor in Guilford's structure of the intellect model. These factors form an integral part of the Elementary Science Study.

II. RELATED RESEARCH

Introduction

A review of the literature related to this area of thinking reveals numerous tests developed to investigate intelligence and very little done about understanding that which the tests were to have measured. Additional study and reading will show a multiplicity of definitions of words related to thinking and intelligence.

Studies concerning intelligence have been carried on since 1870 when Galton (1869) remarked on individual differences. Binet and Simon were commissioned in 1904 to find a procedure for determining how to segregate slow learners in the Paris, France schools. They devised a series of 30 different tests of varying difficulty to aid them in this task. The 1908 revision of their tests was refined to discriminate between normal children. Terman used Binet-type tests successfully in America, added some of his own, and subsequently developed the Stanford-Binet Scale in 1916. Addition of I.Q. index and other modifications have resulted in the present test. Terman used the term "abstract thinking" as a kind of thinking but little was done to actually define this term. The addition of the Wechsler scales of testing has not added precision to the meaning of that which is to be tested. The major asset of the Wechsler scales, according to Guilford (1967, p. 9),

has been, "... the recognition of the multiple aspect of this thing called 'intelligence'..." Wechsler's initial scale, known as the Wechsler-Bellevue Intelligence Scale was composed of tests in two categories, verbal and performance. The verbal tests included: information, comprehension, arithmetic, digits forward and backward, similarities, and vocabulary. The performance tests included: picture completion, picture arrangement, object assembly, block design, and digit symbol. Departing from the unitary concept of intelligence purported by predecessors gave credence to the Wechsler scales.

The major approaches to the understanding of intelligence have been through experimental psychology, genetic investigations and multivariate methods, particularly factor analysis.

Experimental psychologists originally contributed numerous tests of considerable variety upon which Binet and others drew for their test batteries. Experimental psychology has continued to investigate problems of perception, cognition, learning, memory, and problem solving, all of which have direct relevance to the understanding of intelligence.

Genetic investigations have come from Piaget and his coworkers. His view is that understanding how human individuals acquire and use knowledge is the key to understanding intelligence and the operations of the human mind.

Piaget distinguishes three aspects, content, junction, and structure, with respect to general views of intelligence. Content involves the observable aspects of behavior, the source of information with which the psychologist works. Function pertains to broad principles of intellectual activity, principles that apply quite generally regardless of age or state of development of the individual. Structure is equivalent to knowledge. This aspect changes with age and experience. It develops through activity. Piaget is most interested in structure in his writings. Piaget's general theory is in the category of cognitive psychology. In cognitive development, the infant begins life in the external environment with bodily structures that have built into them from hereditary sources, with only a few reflexes, such as sucking, kicking, arm waving, grasping, and looking. It is on the bases of these innate schemes that all knowledge is built through functioning. There are two important ways of functioning in the small child which are assimilation and accommodation. Assimilation is a matter of taking input from sensory inlets and incorporating new elements into the existing structure of knowledge. Accommodation means self-adjustment on the part of the individual, modifying an already existing structure to make it better adapted to the new additions.

Many of the structural concepts of Piaget have much clearer implied relationships to intellectual abilities.

Some of the concepts that have come in for investigation are classes, relations, quantity, number, conservation of quality, and space.

The multivariate approach used in factor analysis is based upon the context that intelligence is in the form of factors of differentiated, basic, intellectual abilities.

It was at this place that Guilford's (1967) structure of intellect theory gave a taxonomy of intellectual abilities in five operations (see p. 10, Figure 1.1) to researchers in this field. One of the thinking operations is divergent-production along with nonverbal-cognitive abilities about which this study is concerned.

Early Studies on Teaching Divergent Thinking

A modern view of trial and error as the basic process in original thinking is provided by Campbell (1960) who suggests trial and error as the basis for all acquisition of knowledge. His viewpoint may be summarized by saying that people think "creatively" by producing ideas or cognitions, some of which turn out to be correct or "useful," some of which do not. Through some second process, men select the useful ideas, and through a third, retain them.

Ray (1967, p. 17) writes,

Many persons assume that original thinkers are born, not made, that is not the position of this book, nor is it the position taken in their research by the psychologists Maltzman and Mednick, who have reported their theories

as to how originality arises and reported also the experiments to which their theories have led them. Their work presumes that people are 'naturally' original -- and that the quantity of originality can be increased.

The "originality" written of above refers to responses by subjects (S) to words read by the experimenter (E) in terms of free-association over two trials. It was shown by Maltzman (1960) that the second trial produced more "uncommon" and "original" responses by the Ss. Subsequent studies using responses from previous experiments did not produce originality. Another found originality lasting for two days although it had decreased when compared with a one-hour lapse from the testing time.

According to Ray (1967, p. 21), Gallup (1962) repeated Maltzman's standard experimental procedure and found no increase in originality at all. Ray (1967, p. 21) concludes that,

...originality as defined by Maltzman can be produced in this fashion, but that there is not yet enough evidence to allow exact specification of the conditions under which the phenomenon will occur or appear.

Maltzman's (1960), p. 16) own conclusion is,

The study reported here ... leads some support to the hypothesis that originality can be learned in the same fashion as other forms of operant behavior.

Mednick (1962) has constructed a test for selecting creative individuals based upon his definition of "creative" which includes not only new ideas (divergent-productive thinking) but uncommon ones. However, utilizing their own procedure along with Mednick's test, Maltzman, Belloni, and Fishbein found no difference between Ss of high and low originality with word-association hierarchies. In the words of Ray (1967, p. 26),

Such inconclusive results are included ... to convince the reader that work in this field has only started, and that there is a great deal to be done. But at least it seems possible to perform experiments here, in what is possibly the most complex area of human behavior.

Creativity as Related to Divergent Thinking

Definitions of creativity have been formulated in various ways and means. Some definitions were formulated in terms of a product (invention and discovery, for example); others in terms of a process, a kind of person, or a set of conditions. The production of something new (to the individual or to the culture) is included in most definitions. Some writers feel creativity must be different from conformity and as requiring non-habitual rather than habitual behavior.

Torrance (1966, p. 8) defines creativity as a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on;

identifying the difficulty; searching for solutions, making guesses, or formulating hypothesis about the deficiencies; testing and retesting these hypothesis and possibly modifying and retesting them; and finally communicating the results.

This definition describes a natural human process. It enables one to begin defining operationally the kinds of abilities, mental functioning, and personality characteristics that facilitate the process.

A type of investigation of originality different from those previously discussed is that of J. P. Guilford. Guilford's work is concerned with various measurements of intellectual abilities with the aims of distinguishing one sort from another and investigating the components of each sort. One of these abilities is originality (which he calls creativity).

On the basis of his work, Guilford has produced a "Structure of Intellect" (1966). This structure assumes that intellectual abilities are divided into five large classes: one memory class and four thinking classes. The thinking abilities are grouped into cognition, evaluation, convergent production, and divergent production. Guilford says of them (1967, p. 27),

The cognitive abilities have to do with the discovery of new information or the recognition (rediscovery) of old information. The productive abilities have to do with the use of information to effect certain outcomes.

The evaluative abilities have to do with decisions as to the goodness, accuracy, suitability, or other forms of desirability or undesirability of information or of products.

The productive abilities are divided into convergent and divergent: "a distinction between thinking that converges upon one right answer and thinking that goes off in different directions." The divergent thinking is most like the sort of thing called originality.

Within the class of divergent abilities, Guilford suggests several factors: word fluency, associational fluency, ideational fluency, and spontaneous flexibility.

Contemporary Studies on Divergent-Productive Thinking

Nine areas have been investigated regarding divergent thinking. Those areas receiving the most emphasis are: Intelligent Quotient (IQ), Memory, Stress, Mathematics, Programmed Instruction, Teacher Interaction with Students, School Atmosphere, and Methods of Teaching.

Anderson (1968) found tests of divergent thinking to be less valid when administered to intellectually superior and retarded students. He concluded that divergent thinking is related to field-independence, a type of cognitive style or global field of approach.

Dellas (1970) found that operationally defined creativity could be increased by visual and effective experiences. A low correlation was found to exist between intelligence

and creativity. She also concluded that while divergent thinking is differentially related to intelligence, it is relatively independent and may be considered multidimensionally, its various components being independent.

Smith (1971) concluded that students with I.Q.'s below 120 may be good convergent achievers, but are not typically good divergent achievers. He states that, "Apparently, a generally high level of intellectual ability is necessary for divergent achievement."

Guilford (1967) found little correlation with I.Q. and so a paradox between his and Smith's results exist.

Pollert et al. (1969) explored the role of memory in divergent thinking and found that it, "may play more important roles in divergent thinking than has formerly been recognized." In addition he found that certain memory abilities may be more important than others for specific types of divergent thinking performances.

Krop et al. (1969) investigated the role of induced stress on divergent and convergent thinking and found that certain "core" abilities may be impaired.

Vaughan (1969) supports a school atmosphere avoiding stressful situations when he writes,

Creativity ... is ... like happiness, always unattainable when directly sought, but to be approached indirectly in an atmosphere of acceptance ... The teacher and the school in American best would serve in this development of students' attitudes, sensitivity, and

character indirectly by providing an atmosphere of receptive listening, rather than persistent insistence on authority. An insistence on authority and the censure of divergent thoughts is believed to be a major cause for the loss recorded in the level of creative ability of our youths.

Olton (1969) studied the effects of a self-instructional programmed method for teaching productive thinking skills in fifth and sixth grade children. His findings support his hypothesis that considerable improvement in generating ideas of high quality, asking relevant questions, and being sensitive to discrepancies of a situation can be taught. Utilizing the Productive Thinking Program, Series One: General Problem Solving, Wardrop, et al. (1969) found that greater gains in productive thinking skills evolved in classrooms providing support and encouragement for productive thinking.

Stallone (1968) studied the effects of selected induced sets on problems requiring divergent thinking and found groups already identified as divergent increased the performance to the posttest. He concluded that sets induced through divergent thinking exercises seem to elicit significantly increased performance on problems requiring divergent thinking.

A study of significance in support of teacher interaction with students is the study of Haddon and Lytton (1968) which shows that the preponderance of divergent and convergent children are produced in British Informal

Schools in which a relationship between teacher and student is such that a child's ability to think adventurously and in new directions is fostered. Haddon and Lytton make the statement,

If the teacher can enter into the child's thinking, if she is prepared to let work develop in unexpected directions according to the child's needs and interests, if she can find and express genuine pleasure in the child's efforts, then self-initiated learning can be developed. It is in this climate that divergent-thinking abilities are seen to flourish.

The majority of research related to mathematics and utilizing materials similar to Geo Block and Tangrams, with which this study is concerned, has been done under the direction of Zolton P. Dienes at the Psycho-Mathematics Research Center of Sherbrooke University, Sherbrooke, Quebec, Canada. One area being studied at the Center is methodology. Dienes, utilizing theories of Borel, Helbert, Russel and others has developed two principles of operation. One is the deep-end principle in which a child is presented with the general principles first and then with the particular cases, rather than the other way around. The second is the dynamic principle in which there is free interaction between the child and the environment and discovery of certain regularities in the environment which lead to further discovery and schematization of the common structures in several concrete situations. The child plays with axiomatic

systems in the same way as he played with the structural components of his environment, and the cycle begins anew.

While seemingly concerned with convergent thinking in teaching children logic, Dienes (1970, p. 55) remarks.

The suggestions ... are intended as guidelines to help teachers to construct such rich mathematical environments in which mathematical problems abounds; and what is also important, in which the possibility always exists of finding solutions to problems already formulated. It is often because we are unable to formulate our difficulties that we are unable to solve them.

This may be interpreted as meaning that unique, original, and clever answers to problems arise after a sequentially developed experience involving convergent thinking as applied to divergent production of an answer. Haddon and Lytton (1968, p. 178) support this when they write, "both high convergent and high divergent thinkers, are indeed often the same children." Dienes' study follows that of Hull's (1968) in which he shows that five-year olds could engage in some high order logical thinking, provided the tasks were suitably chosen and adjusted to the stage of development of the young children, and provided that care is taken in making sure excess verbalism does not stand in the way of concept formation.

Barrish crossed the bounds of mathematics and methods of teaching divergent thinking in his study (1970) when he finds that a method of deductively teaching low cognitive mathematical materials proves superior to an inductive

method. He also points out that levels of divergent production were not related to initial learning nor retention of mathematical generalizations taught regardless of the teaching method.

Teaching Divergent Thinking

Grover (1966) compared two methods of teaching, a divergent and a convergent method, and found no significant mean differences between them. He was also interested in being able to predict achievement of post-divergent and post-convergent tests. The fluency score of the divergent test was the least predictable and had the lowest correlation with the achievement index suggesting that the ability to be fluent was the least related of the tested abilities to typical school performance. He states,

Divergent thinking performance was more predictable for those who had studied by divergent methods than for those who had studied by a convergent method.

Crabtree (1967), utilized divergent thinking versus convergent thinking as criterion variables in determining whether or not structuring of the learning environment affected children's thinking. In the part of her program where a jointly-determined structure, teacher integrative program behavior opened opportunities for discussion periods in which children could explore ideas they had initiated relevant to the subject under study, divergent

thinking occurred more frequently. Where more frequently elicited answers and highly constructed play sequences formed the major role, divergent thinking was reduced.

Bills' (1970) study was an attempt to increase divergent thinking of students with a five week experimental treatment utilizing student inquiry patterned after that developed by Richard Suchman. The results indicated that the inquiry treatment was not able to significantly increase the creative production of the students. An interesting sidelight reported in the study was that the students enjoyed the inquiry sessions and were motivated to seek the solutions to problems from outside sources when discussions were left open-ended. This is supported by Hull (1968) and Vaughan's (1969) study.

A study of importance to the teaching of divergent-productive thinking is a study by Graham (1970) in which certain thinking activities such as classifying, observing, comparing, summarizing, and interpreting, lead to increased verbal flexibility and increased nonverbal fluency, both integral parts of divergent-productive thinking. All of the activities used by Graham are part of the Attribute Games and Problems.

A study of Taylor and McKean (1968) in which success in student teaching by a select group of college students showed that low divergent thinkers were ranked as more successful than high divergent thinkers, even though they

had lower grade point averages. This study may have some significance to teacher education programs. If according to the results of this study, divergent thinking is not rewarded in higher education, and this type of thinking is done by creative and original people, then teacher education programs could be in trouble.

Another study by Huntsberger (1971) using Elementary Science Study Materials-Attribute Game and Problems was carried out to see if divergent-productive thinking skills could be increased. Seven categories, verbal fluency, verbal flexibility, verbal originality, figural fluency, figural flexibility, figural originality and figural elaboration were selected and tested to see if significant increases occurred. Two of the seven areas, figural flexibility and originality were found to have significant increases in divergent-productive thinking.

Summary

Early investigators into intelligence felt that it was a unitary phenomenon. Contemporary development of a theory of the intellect gave workers in the field a taxonomy with which to investigate the multifaceted dimensions of intelligence. Guilford's model lists 120 individual facets.

Early attempts and trials in teaching found that some qualities of divergent thinking could be taught and retained for short periods of time. Later some researchers

felt divergent thinking could not be taught and a paradox developed. Certain aspects of what intelligence is thought to be are being investigated within the taxons of the structure of the intellect.

Little or no correlation has been found to exist between divergent thinking and intelligence quotient. More of a relationship exists with field-independence, a type of cognitive style.

Mathematics has received great attention in the development of divergent thinking skills as they related to the logic of problem solving. The majority of research is being done at the University of Sherbrooke, Quebec, Canada, under the direction of Dr. Zoltan P. Dienes.

Direct correlation has been found by some researchers to exist between the school atmosphere and teacher attitude toward children. Self-initiated learning takes place when the school offers an environment in which the child is treated as humanly as possible and the teacher works outside the framework of an authoritarian atmosphere.

Programmed materials have been developed and used successfully to improve productive thinking skills. Teachers and classrooms that support and encourage productive thinking allow for greater gains to be made by children.

Teaching for divergent-productive thinking skills has utilized structured and unstructured environment, open-ended and elicited answer discussions, divergent and

convergent teaching methods, and inquiry patterns of student involvement in the classroom.

A study by Wardrop, Goodwin, Klausmeier, Olton and Covington (1969), showed that by use of self-instructional programmed lessons designed to teach skills and strategies in creative thinking produced statistically significant increments in thinking and problem solving performance on a wide variety of productive thinking measures. These instructional benefits occurred for virtually all types of students, and were especially marked for students in classrooms having environments which were judged to provide relatively little support and encouragement for the development of productive thinking. These effects were obtained when the materials were used as an entirely self-contained, self-instructional program.

This study is an attempt to show how a readily attainable set of materials will enable a classroom teacher with some training to teach and develop divergent productive thinking skills along with nonverbal cognitive abilities.

III. THE STUDY

The Problem

The basic problem of this study is the statistical comparison of one treatment of Elementary Science materials applied to an experimental group to determine its effect on the acquisition of divergent-productive thinking and non-verbal cognitive abilities with a second group not previously exposed to the treatment materials. This proposal is to be tested with selected elementary children.

Experimental Design

Campbell and Stanley (1963) describe 12 factors which jeopardize the internal and external validity of experimental designs related to educational problems. Two methods for minimizing the effects of these confounding variables are the random assignment of subjects to treatment groups, and the limitation of treatment time.

The experimental design selected for this study consists of posttesting the experimental and control groups only for determining the acquisition of nonverbal cognitive abilities and divergent-productive thinking skills. According to Campbell and Stanley (1963, p. 195),

While the pretest is a concept deeply embedded in the thinking of research workers in education and psychology, it is not actually essential to true experimental design ... the most

adequate all-purpose assurance of lack of initial biases between groups is randomization.

All sixth grade students in Goodview Elementary School were selected and divided into two groups by use of a table of random numbers. A toss of the coin determined the experimental and control group. Twenty students were randomly assigned to the treatment and control groups. This procedure is what Campbell and Stanley (p. 25, 1963) refer to as the Posttest Only-Control Group Design.

Its form is as follows:

R	X	O ₁
R		O ₂

R - indicates random design

X - represents exposure experimental variable

O₁ - represents experimental group

O₂ - represents control group

Major Hypotheses

The following null hypothesis have been formulated in an attempt to contribute supporting evidence toward solution of the problem.

H₀₁: There is no significant difference between the experimental and control groups in their performance on tests for divergent-productive thinking.

H₀₂: There is no significant difference in nonverbal cognitive abilities of students in the control group and in the experimental groups.

The particular divergent-productive thinking skills to be tested are: verbal fluency, verbal flexibility, verbal originality, figural fluency, figural originality, figural flexibility, and figural elaboration (see the following pages 42-43, for a complete description of each category).

Minor Hypotheses

Eight minor hypotheses will be tested which have the following null form.

H₁: There is no significant difference between the experimental and control groups on the test for verbal fluency.

H₂: There is no significant difference between the experimental and control groups on the test for verbal flexibility.

H₃: There is no significant difference between the experimental and control groups on the tests for verbal originality.

H₄: There is no significant difference between the experimental and the control groups on the tests for figural fluency.

H₅: There is no significant difference between the experimental and control groups on the test for figural flexibility.

H₆: There is no significant difference between the experimental and control groups on the test for figural originality.

H₇: There is no significant difference between the experimental and control groups on the test for figural elaboration.

H₈: There is no significant difference between the means of the experimental and control groups.

Population

The population consisted of all the sixth grade students of the Goodview Elementary School from District No. 861, Winona, Minnesota.

Limitations

1. This study was limited to the acquiring of divergent-productive thinking skills and nonverbal cognitive abilities.

2. This study is limited to the sixth grade students of the Goodview Elementary School of District No. 861, Winona, Minnesota.

Assumptions

1. The length of time will allow for acquisition of divergent-productive skills and nonverbal cognitive abilities.
2. Random assignment eliminates the compounding variables of history, testing, regression, and selection.
3. Randomization will assure a lack of initial biases between groups.
4. Randomization will eliminate compounding by reason of maturation.

Delimitations

1. This study does not intend to evaluate teachers, as a group or individually.
2. This study does not intend to make school or district comparisons.

Definitions

Divergent-Productive Thinking - a type of thinking which develops a mental model allowing an individual to take different approaches in solving a problem by forming of mental models from which various selections are used in answering.

Nonverbal Cognitive Abilities - refers to thought processes involving figures, analogies, figure classification,

and figure synthesis: the three subsets of the battery nonverbal cognitive abilities emphasize discovery of the flexibility in manipulating relationships expressed in figural symbols or patterns. Nonverbal cognitive ability is the score a student obtains on this test battery.

Verbal Fluency - the ability of a subject to produce a large number of ideas with words.

Verbal Flexibility - the ability of a subject to produce a variety of kinds of ideas, to shift from one approach to another, or use a variety of strategies in a verbal manner.

Verbal Originality - the ability of a subject to produce ideas that are away from the obvious, commonplace, banal, or established.

Figural Fluency - the ability of a subject to produce a large number of ideas with figures.

Figural Originality - the ability of a subject to produce ideas that are away from the obvious, commonplace, banal, or established when dealing with figural content.

Figural Flexibility - the ability of a subject to produce a variety of kinds of ideas, to shift from one approach to another, or use a variety of strategies in a figural manner.

Figural Elaboration - the ability of a subject to develop, carry out, or otherwise elaborate ideas.

Treatment Sessions

Twenty sixth graders were randomly selected as the experimental group and worked with the experimenter in a regular room provided by the elementary school. Each session was approximately 50 minutes in length conducted from 8:45-9:30 a.m. on scheduled days. The treatment sessions involved an attempt by the experimenter to create a room atmosphere most conducive for encouraging learning. There were twenty-five treatment sessions distributed over three days (Monday, Wednesday, Friday) during the week. At the conclusion of the treatment sessions there were three days of consecutive testing.

Tangrams were initiated first and subsequent activities pursued if a desire to continue was expressed to the experimenter. Geo Blocks were introduced during the first ten sessions after the experimenter was able to determine a desire to work with more varied activities. This process continued until all activities were covered.

Treatment Materials

Tangrams and Geo Blocks units of the Elementary Science Study (ESS) comprised the materials with which the study was concerned.

Tangrams is an ancient Chinese invention and perhaps the oldest and most enduring of geometrix puzzles. It consists of a square divided into seven geometric shapes; two

large triangles, a medium triangle, two small triangles, a square, and a rhomboid. The Chinese name is chi ' i ch ' iao t ' u, meaning "ingenious seven piece plan." A great number of geometric and pictorial arrangements can be made with these pieces.

Each box of Tangram Pieces contains four plastic tangrams, two white and two black. Each package of Tangram Cards contains 121 patterns which the experimenter can match by placing the tangram pieces either on or alongside cards. The Tangram cards are grouped as follows: Set I has two patterns involving only two pieces, six patterns that require three pieces, and nine patterns that call for four pieces or seventeen patterns in all. Set II has 27 patterns, all of which require five pieces (everything but the two large triangles). Set III has 77 patterns that involve all seven pieces. Four students worked with a single box of Tangram Pieces - each child supplied with his own Tangram. They then share a set of Tangram Cards.

Geo Blocks are pieces of hardwood in a variety of shapes and sizes. The smallest is a half-inch cube; the largest is a 2" x 2" x 4" oblong. These blocks are smaller than kindergarten blocks, so they can be used in a variety of places and spaces. Because the blocks come in shapes and sizes not usually found together in other sets of blocks, they lend themselves to a wide variety of structures and designs - some simple, some complex. The

particular shapes and sizes were selected with an eye both for their volumetric relationships and for their usefulness in making intricate constructions. There are only three blocks in the sets which cannot be made by putting together other blocks. There is a large quantity of small blocks and a comparatively small quantity of larger blocks. This forces users to substitute many smaller blocks for one large one when the supply of large ones is exhausted. In making a large shape out of smaller ones, a child develops a feeling for equivalent volumes in context that is determined by his own needs and interests.

Children enjoy working and building with blocks. This natural tendency to build provides an outlet for creative energies in much the same way that art work and creative writing do.

Blocks are ideal materials for helping younger children gain some feeling for surface area and volume relationships. A group of blocks can be arranged and rearranged in a variety of shapes, but they remain the same blocks with the same total volume. It was noted that some children grasp this intuitively and others do not recognize, when they first begin to build, that a block keeps the same volume in any arrangement with other blocks.

Three items are available in teaching with Geo Blocks. First is a guide which describes some activities to be done. Second is the set of Geo Blocks themselves. Third

is a set of problem cards that pose interesting puzzles for children to explore. By utilizing these materials in a sequence of activities it is the opinion, the hypothesis of this study, that divergent-productive thinking and nonverbal cognitive abilities can be taught or enhanced.

Experimental Activities in the Treatment Sessions

The following sequence of problems and activities comprise the treatment sessions in which the experimental group was engaged.

The Tangrams consisting of seven pieces were given to each student in the experimental group and invited to use the pieces freely in any desired way. Various black and white patterns were made which allowed them to become familiar with shapes and how they fit together. After a short session of making patterns, a rule was introduced that all borders must fit together exactly - no edges can be left sticking out.

The cards were next introduced and the experimental group was asked to place the pieces on them in various patterns. The Tangrams would lend themselves to a variety of problem-solving styles. The problems were approached at "fingertip" level-moving the pieces around until they begin to suggest a vague hypothesis and finally, by accident, fall into a solution. After a while, the Ss begin to recognize the basic relationships among the pieces in Set I.

Some of the experimental Ss group were able to apply their analysis to further problems, while others used only trial and error to visualize possible arrangement of the pieces. A great deal of learning takes place in a relatively short time. What is learned is not how to solve this or that problem, but rather to manipulate the pieces in all their variety.

Another Tangram activity was to make Tangram files. Experimental subjects Ss were encouraged to invent their own patterns. Most designs were geometric, but some were pictorial.

Once students became skillful with Set III, they were encouraged to try to match a pattern without placing the pieces on the design itself. For many, this presented a new challenge. Six patterns in Set III required working off the card because of being reduced in size. Working off the card requires a certain amount of visual manipulation of the pieces, especially when the pattern is not full scale. The Ss would also try to visualize solutions to the patterns that are not reduced usually in stages. First, a pattern is tried by allowing just one trial placement of each piece. Then they were to indicate where several pieces will fit on a pattern without placing any of them. Finally, they attempt to draw a diagram of the solution without touching any pieces or even looking at them. A

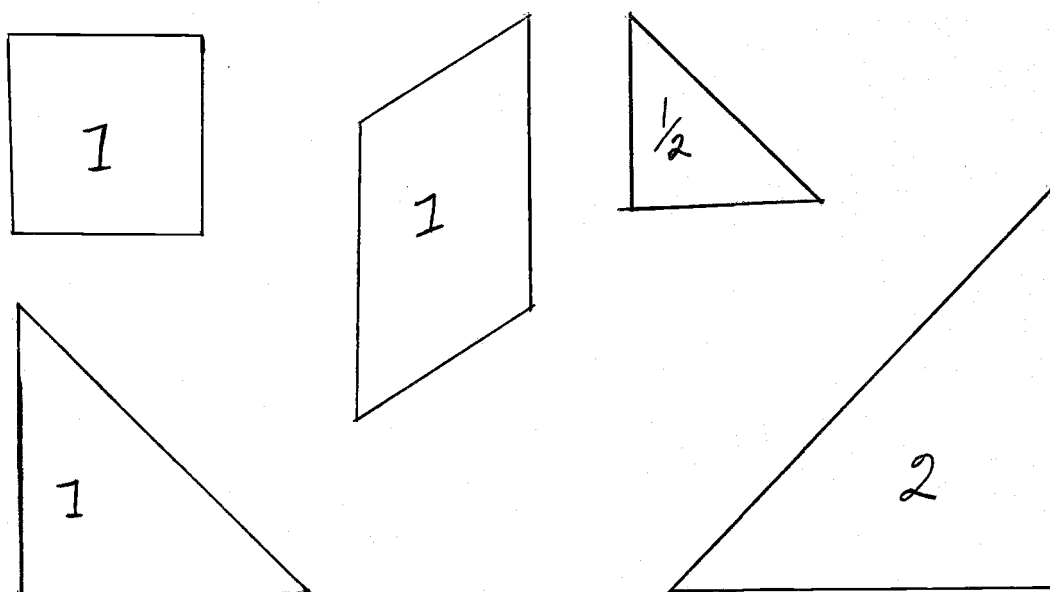
more difficult task was to study a pattern and then try to build it without looking back at the pattern.

Because of the strong perpetual impact and intrinsic interest the students have with Tangrams, this problem fits into a category called, by Hawkins (1965, p. 18), "messing about." This is a time when the Ss are experimenting with symbol systems and systems of representation. This type of activity according to Hull (1968, p. 65) states,

The child who has had ample opportunity to create systems of his own may be better prepared to explore those presented to him in problem-solving situations.

Another activity dealt with squares and areas. Because the Tangram pieces are so closely related to one another geometrically, they enable a student to investigate area without having a background in geometry. The seven piece square was taken as the basic unit. The following questions were then asked. How many unit squares large is the seven-piece square? How many unit squares large is the five-piece square? How many other squares can you make from various numbers of pieces, and how large are they? If you use two, three, or four tangrams together, how many other squares can you make? Can you predict what size squares can be made from these groups?

The area of any one piece can be expressed simply in terms of any other piece. If the square is taken as the basic unit of area, the following relationships exist:



There is no need for children to "learn" these proportions formally. If they are consistently successful with the puzzles, they very likely use such knowledge instinctively, without even realizing they have it.

Many of the problems in Set II, and practically all in Set III, can be solved in more than one way. The great majority are simple reversals or substitutions. Some, however, are legitimate and strikingly different versions of the same pattern and are quite exciting to discover. This writer observed that the experimental group would rarely find them on their own, because of eagerness to work through all cards and not taking time to reflect on each problem.

The process of identifying pieces missing from a subset is complicated, although it may be carried out swiftly when one thinks about the task analytically. After an initial awareness that what is perceived is not random, divergent production of relations and divergent production of classes are involved in producing a diversity of ideas about an approach to solving the problems and the ability to think of tangrams that fulfill particular requirements of meaning within the pattern.

The thought process involving figures and analogies and analysis of a figure to synthesize a new figure are exhibited in working with Tangrams. Discovery and flexibility in manipulating relationships are expressed as shown in the patterns worked out by the students which are Nonverbal Cognitive Abilities.

This approaches Figural Elaboration because the student develops and carries out, or elaborates on the original plan.

Geo Blocks were used after the introduction to Tangrams. The students were given a complete set of 300 blocks and allowed to "mess around" in the first two sessions. The natural tendency to build provided an outlet for creative energies. Groups of blocks were arranged and rearranged in a variety of ways. It was fairly easy to observe student familiarity with volume relationships as they worked with the Geo Blocks. The blocks arranged in one

construction could be arranged into another construction or the building created looks quite different if viewed from another angle. Two students working together would construct two buildings which were similar in every way except that one is larger or smaller than the other. Some students observed that a three-dimensional construction could be represented by a two-dimensional projection as occurs in maps.

It became apparent to the experimenter that block play forms the foundation which assists the student to think in terms of the three-dimensions of space. This would aid in developing what Guilford calls Figural Originality, Flexibility, and Elaboration.

After allowing the students to work alone or in small groups, various structured activities were presented.

An activity usually done was building of various types of towers. Structures were attempted that resulted in being as tall as the person building them.

A question posed was - "What is it about the blocks in a straight-sided tower that gives the tower straight sides?" This question is not nearly as simple as it sounds. One observer noted that all cross sections of the tower which were parallel to the floor are the same size and all sides of the tower are perpendicular to any of the cross-sections. The terms "congruent" and perpendicular were brought in and discussed.

Another activity or problem that occurred when building a tower with straight sides was what to do when all blocks 2" x 2" were exhausted. It soon developed that some of the group would put smaller pieces together to form larger ones. Triangular prisms were even attempted to be put together, but these would soon slip apart. It was observed that soon some even taped blocks together to get satisfactory results.

Another activity involved tracing around the edge of each face of a block and then asking someone to guess which block you have traced. Eventually, the Ss would realize that you don't need to trace all the faces, that only a few are needed for accurate identification.

A second similar activity requires a shadow screen (a small white sheet) and a bright light. Any block placed between the light and the screen will cast a shadow. Only a limited number of the Geo Blocks can make a particular shadow.

A third way of representing a block in two dimensions was posed as follows: Imagine that no one can talk. The only way people can communicate is by means of paper and pencil. You can also use a ruler. You want to tell a carpenter who has never seen the Geo Blocks how to make a set. How can you show him what to make?

Another use of Geo Blocks was in connection with mapping. Three sets of problem cards were used.

The yellow set has 13 problem cards. Each problem card shows all the faces of a particular block drawn in outline. The experimental Ss were asked to find the block that goes with each card.

The photo set contains 12 groups of photos. Each group includes four different side views, a top view, and one oblique view of a block construction. The experimental Ss were asked to build each construction, using the five photographs as guides. The oblique view would serve as an answer card.

The blue card set had nine problem cards. Each one shows several views of a block structure drawn in outline. The experimental group was asked to build the structure shown.

A direction card is included with each set. The three sets increase in difficulty in the order mentioned above, and the problem cards range from simple to more complex within each set.

This writer feels that the use of problem cards which involve geometric-figural elements will develop nonverbal cognitive abilities. The student must look at constructions from more than one view and see constructions from all sides. This in turn increases flexibility in manipulating symbols and patterns.

Posttests on Divergent-Productive Thinking

Two batteries of test activities, one verbal and one figural of the Torrance Tests of Creative Thinking, Verbal Form A and Figural Form A, were used in this study (Torrance, 1974). The Verbal Test consists of seven parallel tasks, requiring a total of 45 minutes in addition to the time necessary for giving an orientation, passing out booklets, and giving instructions. Each task brings into play different types of divergent-productive thinking. The activities involve: asking questions about a drawing, making guesses about the causes of the event pictured (divergent production of units); making guesses about the possible consequences of the events (divergent production of transformations); producing ideas for improving a toy so that it will be more fun for children to play with (divergent production of implications); thinking of unusual uses of cardboard boxes (divergent production of units and classes); asking provocative questions; and thinking of the varied possible ramifications of an improbable event (divergent production of transformations and of implications).

The Figural Test includes three activities with an overall administration time of 30 minutes. The first task, Picture Elaboration, is designed to stimulate originality and elaboration (divergent production of transformations and of implications). The two succeeding tasks, Incomplete Figures and Repeated Figures, increasingly elicit greater

variability in fluency (divergent production of units); flexibility (divergent production of classes); originality (divergent production of transformations); and elaboration (divergent production of implications).

Choosing of these two tests was due to Torrance's (1966, p. 56) recommendation that they can be used to,

discover effective bases for individualizing instruction. Assessing the differential effects of various kinds of experimental programs, new curricular arrangements or materials, organizational arrangements, teaching procedures, and the like.

Another reason for the choice of this test is that most tests measure some goal or are designed for convergent types of thinking. This study is attempting to identify divergent-types of thinking and the Torrance Tests are designed to measure those abilities.

Posttests on Nonverbal Cognitive Abilities

The Nonverbal Battery, consisting of three separate subtests: Figure Analogies, Figure Classification and Figure Synthesis were also used in this study. Level D for Grade 6 which required a total of 32 minutes in addition to the time necessary for giving an orientation, passing out booklets, and giving instructions was the form used. Test 1, figure classification, requiring 12 minutes, involves a set of figures or drawings that are all alike in some way. The experimental Ss are asked to figure out how they are

alike, and then find in the answer choices that are similar. Test 2, figure analysis, requiring ten minutes, begins with a pair of figures or drawings that are related to each other in some way. In each exercise, the experimental Ss had to decide how the first two figures, or drawings that are related to each other, then after being given a third figure, find one of a group which is related to the third. Test 3, involving figure synthesis, taking ten minutes, involves putting pieces together to make different shapes, just like putting pieces of a puzzle together. In each exercise, the experimental Ss is given two or more pieces and a number of complete shapes. The pieces are solid black; the shapes are shaded with black lines around them. The Ss is asked to figure out whether all the pieces can be arranged so as to cover all of the shaded part and to form the shape made by the black lines. The rules are:

1. All the given pieces must be used for each shape.
2. Each piece can be used only once for each shape.
3. The shaded part of each shape must be completely covered by the piece.
4. No piece can be placed either partly or entirely on top of another piece.
5. The pieces may be turned in any direction or they may be flipped over and turned in any direction to make them fit into the shaded area of the shape.

This test was chosen because the items in the subtests involve neither words nor numbers. The abilities required are nonverbal and this writer feels Tangrams and Geo Blocks will develop these behavioral units.

Test Validity (Nonverbal Cognitive Abilities)

The Nonverbal Cognitive Abilities is a test whose items involve neither words nor numbers and which, through its utilization of geometric or figural elements, take a "fluid" type of ability that is not bound by formal school instruction. The test is "Multi-Level" which indicates that for each separate battery there is a graded series of items divided into eight distinct levels by over-lapping scales. Each successive scale is somewhat more difficult than the one that preceded it, but the difficulty increases by small enough steps so that there is always a level that is of optimum difficulty for any class group, or for an individual student.

The Nonverbal Battery is entirely pictorial or diagrammatic. The subtests are Figure Analogies, Figure Classification, and Figure Synthesis. For the average child or young person, these tests will not predict school performance quite as well as scores based upon the Verbal or Quantitative Battery; however, they permit an appraisal of abstract intelligence which is not influenced by specific disabilities in reading.

The standardization of the Cognitive Abilities Test was a cooperative enterprise involving the publisher and authors of the test battery, the Cognitive Abilities Test, the Iowa Tests of Basic Skills, and the Tests of Academic Progress. The raw score for each pupil was converted into a Universal Scale Score, and distributions of Universal Scale Scores were prepared for students at each age. Using Universal Scale Scores, cumulative frequency distributions were prepared and cumulative percents computed for each age group. Normal deviates corresponding to the cumulative percents were determined. These were multiplied by 16 to give a scale with standard deviation of 16, and 100 was added to convert to a scale in which the average was 100. This provides a conversion from Universal Scale Score to Standard Age Score at each age level.

Content Validity is thought of as how well a test represents or matches some defined domain of ability. In preparing this test, the authors were more concerned with what can be said about the activities called for in the test, than they have with any formal definition of the ability or abilities being measured. They believe the test is characterized by the following statements and that these characteristics describe behavior that it is important to measure in understanding an individual's educational and work potential: (1) The task deals with abstract and general concepts; (2) The tasks require interpretation and

use of symbols; (3) The examinee must deal with relationships among concepts and symbols; (4) The examinee must be flexible in his basis for organizing concepts and symbols; and (5) Power in working with abstract materials is emphasized, rather than speed.

This test is a measure of abstract abilities in pictorial and figural symbols which this writer hopes to be developed by the use of Tangrams and Geo Blocks.

The Nonverbal Cognitive Abilities Test has a correlation of .60 with the Iowa Tests of Basic Skills and .65 with the Test of Academic Progress.

Test Validity (Torrance Tests of Creativity)

Since a person can behave creatively in an almost infinite number of ways and since there is a diversity of definitions of creativity, it is impossible to provide satisfactory evidences in all ways. This problem of validity is readily shown as one reviews the literature.

This writer agrees and feels strongly with the model of Torrance (1974, p. 21) as he states,

It has seemed reasonable to the author to think of creativity as a process. With this approach, one can think in terms of the kinds of abilities necessary for the successful operation of the process in various situations or for the production of various kinds of products. He can think in terms of the qualities of the products resulting from the process. One can think of the kinds of personality characteristics, group dynamic valuables, and

other environmental characteristics that facilitate or impede the kind of functioning described by the process of definition.

Being unable to set forth the universe of possible behaviors of any one individual or group of humans, the Verbal and Figural Form A of the Torrance Test of Creativity Thinking sample a wide range of the abilities in such a universe. They cover many of the facets of divergent-productive thinking referred to in the series of experimental activities in this chapter.

Two features of these tests that make them appropriate to this study and valid in terms of the above, are: (1) To insure content validity, a consistent and deliberate effort has been made to base the test stimuli, the test tasks, instructions, and scoring procedures on the best theory and research now available; and (2) The tests can be administered at all educational levels making it possible to determine whether or not children identified as creative behave in ways similar to the ways in which eminent creative people of the past behaved when they were children.

Test Scoring (Nonverbal Cognitive Abilities)

Scoring directions for the Nonverbal Cognitive Abilities Test used in this study were provided and followed in the Examiner's Manual Cognitive Abilities Test. Directions for administering the tests are given in the manual and were adhered to by this writer.

After hand scoring each test, the raw scores were converted to Universal Scale Scores by use of Table 13, Examiner's Manual Cognitive Abilities Test (p. 94-95). These converged scores are shown in Table 4 presented in the next chapter.

Test Scoring (Torrance Test of Creativity)

Scoring directions for both the Verbal Form A and Figural Form A of the Torrance Tests of Creative Thinking used in this study are provided in the Torrance Tests of Creative Thinking Directions Manual and Scoring Guide. Directions for administering the tests are also given in the manuals and were strictly adhered to by this writer.

For comparative purposes, comparison group norms were supplied in the Torrance Tests of Creative Thinking Norms-Technical Manual, Research Edition (Torrance, 1966). After the scoring of the individual tests is accomplished, the raw scores in each category for each S is converted to a T-score or standard score. Comparison of scores on tests from this study were then compared with the scores supplied in the Norms-Technical Manual, Research Edition. The converted T-scores from the tests in this study can be seen in Table 22 (p. 54).

The tables from the Norms-Technical Manual, Research Edition, used for comparison with the test results from this study were as follows: for the Verbal portion of the

test in this study, the T-Score Conversion Table for Fluency, Flexibility, and Originality of Verbal Form A of the Torrance Tests of Creative Thinking Based on Fifth Grade Data, Table 23 (p. 55) was used; and for the Figural portion of the test in this study, the T-Score Conversion Table for Fluency, Flexibility, Originality, and Elaboration for Figural Form A of the Torrance Tests of Creative Thinking Based on Fifth Grade Data was used.

IV. PRESENTATION AND INTERPRETATION OF THE DATA

Introduction

The purpose of this study was to assess the differential effects of two elementary science study units on the acquisition of divergent-productive thinking skills and nonverbal cognitive abilities by selected elementary school children.

All of the forty sixth-grade students of Goodview Elementary School of the Winona District 861 were randomly assigned to the control and experimental groups. A coin toss determined which class was to be the control. Twenty students were randomly selected and assigned to the experimental and control group. All in the experimental group Ss attended each experimental activity session each day for twenty-five sessions over a period of eight weeks. One student moved from the district during this period leaving a total of nineteen who completed all sessions. Each experimental activity lasted approximately forty-five minutes during the regularly assigned science class time. All of the Ss were tested on the same days at the conclusion of the experimental activities. Testing of the control was done at the same time as the experimental group. Eighteen students of the control completed all of these tests. One had left school for medical reasons and another moved from the district. Testing was done on three

consecutive class periods, Monday, Wednesday and Friday. The control group attended regular science class activities using the Westinghouse Plan materials.

The level of significance for rejection of the various hypothesis in this study was set at the .05 level.

Presentation of the Study Data

Table 4.1 represents the Universal Scale Scores obtained from the basic test data. These scores represent standardized values derived from the raw score. This score, a normalized standard score, is used to enter the age and grade norm tables for all sixth graders (Examiner's Manual Cognitive Abilities Test, 1971, p. 84-85).

The statistical treatment of the data in Table 4.1 was done by using the Students t-test for unpaired data. This formula makes use of unpaired data and this study is testing the difference in the means of two groups by comparing the calculated t-value to the theoretical two-tailed t-value. The test statistic is in the following form:

$$t = \frac{\bar{X}_E - \bar{X}_C}{s \sqrt{\bar{X}_1 - \bar{X}_2}}$$

where \bar{X}_E = the mean for the experimental group

\bar{X}_C = the mean for the control group

and,

$$s_{\bar{x}_1} - \bar{x}_2 = \frac{\overline{2s^2}}{n}$$

where, $s_{\bar{x}_1} - \bar{x}_2$ = the sample estimate of the standard error of $(\bar{x}_E - \bar{x}_C)$

n = the number of subjects in the group

s^2 = a pooled estimate of the variance

Table 4.2 represents the calculated means and resulting Students t-values from which tests of significance were determined for the Thorndike-Hagen Nonverbal Cognitive Abilities Test.

Table 4.3 represents the t-scores obtained from the basic test data of the Torrance Test of Creativity. They represent standardized values derived from Torrance's (1966, p. 54-55) t-score conversion tables based on fifth grade data.

Table 4.4 represents calculated means and resulting Student t-values from which significance was determined.

Table 4.5 represents the calculated means and resulting Students' t-values from which significance was determined from the composite t-scores of each group of Ss.

Test of Major Hypothesis

The data from Tables 4.3, 4.4, and 4.5 was scrutinized to determine whether a significant difference occurred between the experimental and control groups.

Table 4.1. Universal Scale Scores converted from raw score data (Nonverbal Battery) of the Thorndike-Hagen Cognitive Abilities Test.

Control			Experimental		
Student	Raw Score	Universal Scale Score	Student	Raw Score	Universal Scale Score
1	61	127	1	67	137
2	58	123	2	62	128
3	47	110	3	59	124
4	44	107	4	44	107
5	71	147	5	71	147
6	75	121	6	60	125
7	61	127	7	54	118
8	52	116	8	57	121
9	62	128	9	41	104
10	60	125	10	65	133
11	55	119	11	59	124
12	51	115	12	68	137
13	31	101	13	63	129
14	53	117	14	66	135
15	52	116	15	68	140
16	56	120	16	42	136
17	50	114	17	52	116
18	65	113	18	68	140
			19	73	154

Table 4.2. Calculated means and student's t-values for the Nonverbal Battery.

Control Means	Experimental Means	Student's t-value
119.222	129.211	2.636 ^(c)

(c) Significant at .02 level.

Table 4.3. T-scores converted from verbal and figural test scores.

Student	Verbal Fluency	Verbal Flexibility	Verbal Originality	Figural Fluency	Figural Flexibility	Figural Originality	Figural Elaboration	Composite T-Scores
1	33	40	48	56	34	62	67	340
2	40	52	48	32	35	38	73	318
3	41	29	40	74	45	44	44	317
4	38	36	37	40	45	44	51	291
5	41	28	39	55	60	50	36	309
6	49	59	42	47	44	56	69	366
7	28	37	51	48	44	41	63	312
8	26	61	40	59	50	58	63	357
9	37	29	29	34	44	36	62	271
10	33	24	46	37	57	52	70	319
11	29	30	23	30	40	39	41	232
12	30	36	27	42	38	31	38	242
13	33	29	46	48	39	40	40	275
14	42	37	40	51	20	36	50	285
15	36	40	38	29	41	32	62	278
16	37	20	37	42	37	38	49	269
17	38	27	29	50	37	40	50	271
18	39	33	37	51	36	31	49	276

Control

Table 4.3. (continued)

Student	Verbal Fluency	Verbal Flexibility	Verbal Originality	Figural Fluency	Figural Flexibility	Figural Originality	Figural Elaboration	Composite T-Scores
1	39	44	48	57	62	64	68	382
2	42	56	43	52	46	44	86	369
3	47	56	41	30	59	54	61	348
4	41	31	56	61	38	38	60	325
5	36	40	51	51	58	64	78	378
6	46	61	56	70	57	76	60	426
7	42	39	42	34	54	83	87	381
8	44	48	45	59	76	41	54	367
9	36	29	39	58	60	66	61	349
10	38	38	42	45	46	54	55	318
11	42	31	39	44	37	62	62	317
12	40	37	40	39	42	58	70	326
13	27	42	29	42	55	56	39	291
14	41	40	46	44	50	57	48	326
15	46	47	38	50	48	46	51	326
16	49	53	56	48	60	61	53	371
17	41	61	51	50	49	49	58	359
18	46	60	48	56	52	53	60	365
19	42	52	41	50	50	51	50	336

Experimental

Table 4.4. Calculated means and student's t-values from unpaired t-test.

	Control Means	Experimental Means	Student's t-value
Verbal Fluency	36.1111	41.3158	2.9429 (b)
Verbal Flexibility	36.4444	45.4737	2.5955 (c)
Verbal Originality	38.7222	43.1579	1.60137 (d)
Figural Fluency	45.8333	49.4737	1.04377
Figural Flexibility	41.9444	52.6316	3.78194 (a)
Figural Originality	42.6667	56.6316	4.07982 (a)
Figural Elaboration	54.2778	60.1579	1.51379

(a) Significant at the .001 level.

(b) Significant at the .01 level.

(c) Significant at the .02 level.

(d) Significant at the .20 level.

Table 4.5. Calculated means and student's t-value from t-test on composite scores.

	Control	Experimental
Means	295.667	350.474
Students' t-value	4.93036 (a)	

(a) Significant at the .001 level.

Based on statistics summarized in Tables 4.3, 4.4, and 4.5, the hypothesis:

H₀₁: There will be no significant difference in mean scores between the control and experimental groups in their performance on tests for divergent-productive thinking.

was rejected. That is, the treatment made a difference in all categories of divergent-productive thinking skills except figural fluency and figural elaboration. The statistics show that sufficient time and effort spent with the experimental activities resulted in significant differences.

The data from Tables 4.1 and 4.2 was scrutinized to determine whether a significant difference occurred between the control and experimental groups.

Based on the statistics summarized in Tables 4.1 and 4.2, the hypothesis:

H₀₂: There is no significant difference in means in nonverbal cognitive abilities of students in the control group and in the experimental group in their performance on tests for nonverbal cognitive abilities.

was rejected. That is, the treatment made a difference in thought processes involving figures, analogies, figure classification and synthesis. This writer feels the activities used in Tangrams and Geo Blocks produce a significant difference in discovery of flexibility in manipulating relationships expressed in figural symbols or patterns.

Test of Minor Hypothesis

The data from Table 4.3 was subjected to the student's t-test to determine whether or not a significant difference occurred between the means of the experimental and control groups in any of the seven categories: verbal fluency, verbal flexibility, verbal originality, figural fluency, figural flexibility, figural originality, and figural elaboration. The statistical results from these tests can be observed to have significant differences.

Based on results summarized in Table 4.4, the hypothesis:

H_1 (minor): There will be no difference between the control and experimental group means on the test for verbal fluency.

was rejected at the .01 level. This rejection reflects the ability of the experimental group students to produce a larger number of ideas with words when compared to the control group of students. The activities used in the treatment group facilitate the causal and predictive kinds of thinking called for in the "Guess Causes" and "Guess Consequences" activities.

Based on results summarized in Table 4.4, the hypothesis:

H₂ (minor): There will be no difference between the experimental and control group means on the test for verbal flexibility.

was rejected at the .02 level. This implies that the experimental group subjects Ss produce a variety of kinds of ideas, are better able to shift from one approach to another, or are able to use a variety of strategies.

Based on results summarized in Table 4.4, the hypothesis:

H₃ (minor): There will be no difference between the experimental and control group means on the tests for verbal originality.

was rejected at the .20 level. Thus, it is felt that the treatment may allow an individual to produce ideas that are away from the obvious, commonplace, or established in terms of generating original ideas.

Based on results summarized in Table 4.4, the hypothesis:

H₅ (minor): There will be no significant difference between the experimental and control group means of the test for figural flexibility.

was rejected at the .001 level. There is sufficient evidence that the experimental group was more effective in producing many different kinds of configurations from a basic

idea. The experimental group was able to view sets of parallel lines in a number of different ways.

Based on results summarized in Table 4.4, the hypothesis:

H₆ (minor): There will be no significant difference between the experimental and control group means on the test for figural originality.

was rejected at the .001 level. That is, there is much evidence that the experimental subjects were more effective in producing more original kinds of configurations than were the non-treatment subjects.

Based on the results summarized in Table 4.5, the hypothesis:

H₈ (minor): There will be no difference between the means of the experimental and control groups on the Verbal and Figural Tests of Creativity.

was rejected for the composite t-scores at the .001 level. That is, there is considerable evidence to infer that the treatment was more effective in terms of developing divergent-productive thinking skills than in the control group. This writer feels the ESS (Elementary Science Study) units of Tangrams and Geo Blocks aid considerably in the teaching of divergent-productive thinking skills. The activities encourage individuals to take different approaches in solving problems. The individual and small group approach requires

each student to be actively involved which also aids in development of these skills.

Summary

Based upon the unpaired t-test there was found to be significant differences in all but two categories.

The null hypotheses:

H_{01} : There will be no difference between the two groups in their performance on tests for divergent-productive thinking;

H_{02} : There is no difference in nonverbal cognitive abilities of students in the control group and in the experimental group.

were both rejected at the .001 level. H_1 (minor) was rejected at the .01 level for verbal fluency. H_2 (minor) was rejected at the .02 level for verbal flexibility. H_3 (minor) was rejected at the .20 level for verbal originality.

H_5 (minor) was rejected at the .001 level for figural flexibility. H_6 (minor) was rejected at the .001 level for figural originality.

Based upon the composite data from Table 4.5, the null hypothesis:

H_8 (minor): There will be no difference between the means of the experimental and control groups on the tests of verbal and figural fluency.

was rejected at the .001 level. There were significant differences between the two groups to give evidence that

Tangrams and Geo Blocks develop divergent-productive thinking skills along with the ability to develop nonverbal cognitive abilities.

V. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to assess the differential effects of the elementary science materials, Geo Blocks and Tangrams, of the Elementary Science Study, on the acquisition of divergent-productive thinking skills and non-verbal cognitive abilities by selected elementary school children. The criterion instruments used in this study were the Torrance Test of Creativity, Figural Form A and Verbal Form A, and the Thorndike-Hagen Nonverbal Cognitive Abilities Test. The statistical treatment consisted of the Students' t-test to determine if the means of the two groups were statistically significant.

The experimental activities involving the Ss were designed in a way to develop figure analogies, figure classification, and figural synthesis by use of puzzles and blocks. The puzzles presented were pictorial or diagrammatic and used divergent-productive modes of thought because many problems presented led to more than one solution. The activities involved the manipulation of blocks or pieces in a framework of activities which required the Ss to create new ideas (divergent-production of thought).

Other areas using nonverbal abilities (seeing block patterns from four sides or points of view) were brought in to play in various experimental activities.

During the treatment sessions, an attempt was made by the experimenter to keep an atmosphere conducive to inquiry learning by having available numerous activities so each Ss could work alone at his or her own pace.

The experimental Ss were randomly selected sixth-grade students who had not had previous experience with the materials. The Ss were obtained from the Goodview Elementary School of District 861, Winona, Minnesota. The experimental group worked with the activities for eight weeks, three times a week, with each experimental activity lasting approximately forty-five minutes during the time normally used as a science period. All in the experimental group completed all the experimental activities except one who moved from the district. The control group were the remaining sixth-grade students of the Goodview Elementary School who attended the regular science activities at the same time with their regular teacher. All but two completed their regular science activities. One moved from the district and one left for medical reasons.

The Goodview School is an open school with an enrollment of approximately 500 students including kindergarten through sixth grade. This school has a kindergarten and three pods. Each pod has approximately 150 students. The Westinghouse Plan (Planned Learning According to Need) is employed in this school. A computer is used to record activities and notes or records the progress of each student.

The treatment made a difference in all categories of divergent-productive thinking except figural fluency and figural elaboration. The treatment also made a difference in the category of nonverbal abilities. This data supports the inference that sufficient time (eight weeks), a variety of activities, and the effort put forth with the experimental activities resulted in a significant overall difference on all of the tests.

The results of the data from Table 4.4 indicate that the treatment effects were significant in five categories of divergent-productive thinking; verbal fluency, verbal flexibility, verbal originality, figural flexibility, and figural originality.

The level of significance was .20 for the verbal originality and this writer still rejects the hypothesis:

H₃ (minor): There will be no difference between the experimental and control groups on the tests for verbal originality.

because this is part of the divergent-thinking skills involved in an Ss ability to produce ideas that are away from the obvious, commonplace, banal, or established. Torrance (1974, p. 57) writes,

The person who achieves a high score on Verbal Originality usually has available a great deal of intellectual energy and may be perceived as rather nonconforming. He or she is able to make big mental leaps or "cut corners" in obtaining solutions, but this does not mean that the person is erratic or impulsive. In fact, the making of

original responses requires the ability to delay immediate gratification or reduction of tension in order to get away from the obvious, easy, but low quality response.

The obvious importance of this mental skill is the reason why this hypothesis was rejected.

Conclusions

Raw data from the test results was compared with standardized values and converted to Universal Scale Scores on the Thorndike-Hagen Nonverbal Cognitive Abilities Test. Raw data from the test results was compared with standardized values derived from Torrance's t-score conversion tables based on fifth grade data and converted to t-scores. Student's t-test was used to determine the level of significance of the converted t-scores of both tests. From these results it can be inferred that the treatment effects are significant in the area of nonverbal cognitive abilities. The hypothesis that there is no significant difference in means in nonverbal abilities was rejected at the .02 level.

The significance of .02 indicates that Geo Blocks and Tangrams significantly develop nonverbal abilities such as the processes involved in working with figures. The Ss were better able to work with figures or drawings and see relationships involving geometric patterns than the control. The Ss were also able to do considerably better in arranging pieces together to make different shapes as is done in

working on puzzles. The statistics indicate that working with Geo Block mapping whereby the Ss had to look at figures from four sides plus a view from the top increases significantly the ability to work in three dimensions.

The other major hypothesis that there will be no difference in mean scores between the control and experimental groups in their performance on tests for divergent-productive thinking was rejected at the .001 level. This indicates that the experimental Ss were able to produce a large number of ideas with words, increased in ability to produce a variety of kinds of ideas or shift from one approach to another, and were more flexible in viewing, manipulating, and using figural elements.

The purpose of this study was to investigate the educational value of two selected Elementary Science Study Units. The effects of Geo Blocks and Tangrams on the acquisition of divergent-productive thinking and nonverbal cognitive abilities was investigated. The Guilford structure of intellect model has divergent thinking as one of its operations. This study shows that these types of thinking skills can be taught. The study also indicates that something besides content or knowledge is gained from the units of Geo Blocks and Tangrams.

This study indicates that individualized instruction as was carried on in the open classroom is effective. Students prefer to learn in creative ways, by experimentation,

manipulation, discovery and inquiry rather than by deliberate authoritarian means.

Recommendations for Additional Study

Based upon the data gathered in this study, the investigator recommends that:

1. The ESS (Elementary Science Study) unit of Attribute Games and Problems be tested in an open classroom using the design of this study. Previous studies were carried out in a traditional classroom setting.
2. This study be repeated in a traditional classroom where the units would be taught by the regular classroom teacher. This study was taught and carried out by the experimenter in an open classroom.
3. That only one unit be used in a study to determine its effectiveness in producing divergent-productive thinking. This experimenter used two units (Geo Blocks and Tangrams), and it is not known which unit is most effective in producing divergent-productive thinking and nonverbal cognitive abilities.
4. This study be carried out with an older age group, preferably at the senior high level to see if divergent-productive thinking and nonverbal abilities might be increased. The majority of studies have been done at the elementary level, usually in grades five and six.

5. The experimental group be retested at a later date to see if divergent and nonverbal thinking skills are retained.

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